IS 12065 (1987): Permissible limits of noise level for rotating electrical machines [ETD 15: Rotating Machinery]

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Indian Standard

PERMISSIBLE LIMITS OF NOISE LEVELS FOR ROTATING ELECTRICAL MACHINES

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Indian Standard

PERMISSIBLE LIMITS OF NOISE LEVELS FOR ROTATING ELECTRICAL MACHINES

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Indian Standard

PERMISSIBLE LIMITS OF NOISE LEVELS FOR ROTATING ELECTRICAL MACHINES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 January 1987, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The methods of measurement used in this standard have been selected from IS : 6098-1971*.

0.3 This standard intends to establish the limits of maximum permissible airborne noise levels emitted by rotating electrical machines.

0.4 Acoustic quantities can be expressed in sound pressure terms or sound power terms. The use of sound-power level, which can be specified independently of the measurement surface and environmental conditions, avoids the complications associated with sound pressure levels, which require additional data to be specified. Sound-power levels provide a measure of radiated energy and have advantages in acoustic analysis and design.

Sound-pressure levels at a distance from the machine may be required in some applications, such as hearing protection programmes. It was agreed that this standard was only concerned with the physical aspects of noise, to express limits in terms of sound power and not to give guidance for calculation of sound-pressure levels at a distance, derived from sound power values. These calculations require knowledge of machine size, operating conditions and the environment in which it is installed. Indications for such calculations taking into account environmental factors could be found, if needed, in classical text books on acoustics.

0.5 In the preparation of this standard, assistance has been derived from the following:

BS 4999 : Part 51:1973 Specification for general requirements for rotating electrical machinery: Part 51 Noise levels, issued by the British Standards Institution (UK)

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*Methods of measurement of the airborne noise emitted by rotating electrical machinery.

IEC Pub 34-9 (1972) Rotating electrical machines : Part 9 Noise limits, issued by the International Electrotechnical Commission.

Doc : 2 (Sectt), 684 IEC Draft Revision of Pub. 34-9 (1972) : Rotating electrical Machines: Part 9 : Noise Limits, issued by the International Electrotechnical Commission (IEC).

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This Indian Standard specifies methods of measuring and classifying the acoustic noise emitted by rotating electrical machines (excluding small power machines and machines for traction vehicles) on no-load.

1.2 A noise classification in terms of dB (A) sound power level is given. Methods are also included for correcting for the presence of pure tones.

1.3 Upper limits of dB (A) sound power level for machines rated up to 16 MW are given in Appendix D. Limits for larger machines are not at present given in this standard and should, therefore, be agreed to between the manufacturer and the purchaser.

1.4 Recommendations are included in Appendix B for methods of assessing noise from machines on load.

1.5 This standard covers measurements normally made in free field conditions. Where free-field conditions cannot, in practice, be achieved, recommendations are given in Appendix C for measurements made in semi-reverberant conditions.

2. TERMS AND DEFINITIONS

2.0 For the purpose of this standard the following definitions shall apply.

2.1 Sound Pressure Level *L* — The sound pressure level is defined by $20 \log_{10} \frac{p}{p_0}$ decibels (dB) where p is the measured rms sound pressure and p is the reference rms sound pressure of 2×10^{-5} N/m² (Pa).

*Rules for rounding off numerical values (*revised*).

2.2 Sound Level — The sound level in (dB) is defined by 20 $\log_{10} \frac{p_n}{p_c}$ where p_n is the rms sound pressure due to the sound being measured weighted in accordance with the curves A, B and C (*see* IS : 9779-1981*).

NOTE — Sound levels are expressed in dB (the weighting curve used is always to be stated) [for example, sound level A = x dB, or sound level = x dB (A)].

2.3 Noise Spectrum — A spectrum showing the sound pressure level distribution throughout the frequency range. The appearance of the spectrum depends upon the filter band width characteristics of the analyzer used.

2.4 Band Pressure Level — For a specified frequency band, the effective unweighted sound pressure level corresponding to the sound energy contained within the band.

2.5 Sound Power Level L_w — The sound power level is defined as:

$$10 \log_{10} \frac{W}{W_0} \text{ in decibels}$$

where

W = measured sound power (watts); and

W_0 = reference sound power expressed in the same unit as W; W_0 is equal to 10^{-12} watt (or 1 pW).

NOTE—L_{WA} is a weighted sound power level determined in such a manner that the acoustic power level in each of the frequency band is weighted according to the (A) scale.

2.6 Prescribed Path — An imaginary line around the machine as given in this standard and along which the measurement points are located.

NOTE — As this standard covers electrical machines of all shapes and sizes, it was found impracticable to define a prescribed path as given in IS : 4758-1968†. The prescribed paths are defined which can be used in all cases.

2.7 Equivalent Hemisphere r — A hypothetical hemisphere surrounding the mechine on which the measurements are assumed to be made, its radius being denoted by r_s and whose centre is in the plane of the floor.

2.8 Background Noise — Any noise at the points of measurement other than that of the machine being tested. It also includes the noise of any test equipment.

2.9 Acceptability Rating — An (A) weighted sound power level corrected for the presence of pure tones.

*Specification for sound level meters.

†Methods of measurement of noise emitted by machine.

3. TEST METHOD I

3.0 This clause describes the procedure to be used to establish the (A) weighted sound power level of the machine. It is assumed that the machine is a noise source radiating in free-field conditions over a reflecting plane which is considered as its base. Where free-field conditions cannot in practice be achieved, the method may still be used but the sound power level obtained will be slightly higher. No correction shall be made in this respect.

3.0.1 The (A) weighted sound power levels determined in accordance with test method I shall not exceed those given in Appendix D appropriate to the rated output, speed and type of enclosure.

3.0.2 In all cases where the (A) weighted sound power level of a machine is greater than 93 dB (A) or one or more tones are prominent, noise measurements shall be made in accordance with Test Method II (*see* **4**).

3.1 Test Conditions

3.1.1 Test Environment — The suitability of any given test environment shall first be ascertained by making a test of room suitability as detailed in **3.3.1**.

3.1.2 Background Noise — The background noise reading when the machine is not on test shall be determined at the same points as for the test. The reading at each point with the machine on test ought to exceed that due to the background alone by at least 10 dB. When the differences are less than 10 dB, corrections can be obtained from the background correction curve shown in Fig. 1.

3.1.2.1 Alternatively, the background correction may be made as follows.

3.1.2.2 Using the table in Appendix E, find the number in column 2 corresponding to the total noise level in column 1 and subtract from this the number in column 2 corresponding to the background level. The result of this subtraction will correspond, in column 2, to the source level in column 1, rounded to the nearest whole number or whole number plus 0·5 dB (*see* example 3, Appendix A).

3.1.2.3 In the case of rapidly fluctuating background noise a difference of 10 dB between the maximum background level and the machine on test is essential.

3.1.2.4 When corrections of 3 dB or greater are applied, the corrected levels should be indicated in brackets.

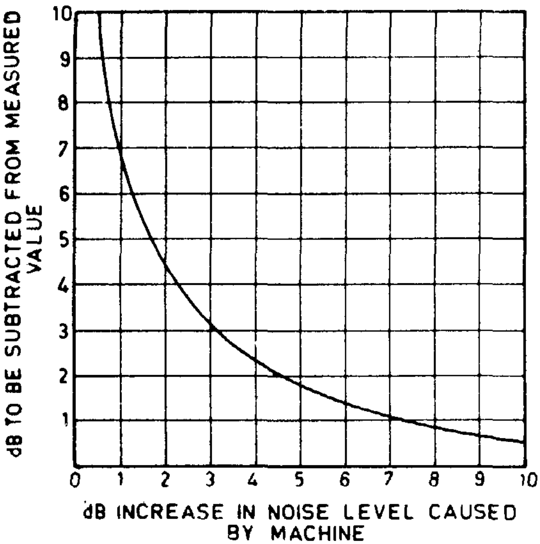


Fig. 1 Background Noise Correction Curve

3.1.2.5 When the increase in noise level due to the machine is less than 3 dB, measurements, in general cases to have any significance.

3.1.3 *Operating Conditions of Machine on Test* — For the purpose of the test, the following conditions shall be observed:

a) The machine shall be run on no-load. Synchronous machines shall be run at unity power factor;

b) The machine shall be in its fully-assembled condition, and uncoupled;

c) ac machines shall be supplied at rated voltage and frequency;

d) Machines shall be run as nearly as possible at rated speed, or at the highest speed in the range, if there is a speed range; and

e) Machines designed to operate at two or more discrete speeds shall be tested at each speed.

3.1.4 *Mounting of Machine*—Structure borne vibrations from a machine to its mounting, or other parts of the test room, can influence the sound pressure level in the test room. It is permissible to minimize such effects by, for example, mounting the machine on suitably designed resilient mountings.

3.2 Measuring Instruments

3.2.1 *Grade* — The sound level meter shall comply with the requirements of IS : 9779-1981* and shall be used on the (A) weighted scale.

3.2.1.1 Instructions on the use of the equipment shall be complied with to ensure that the intended degree of precision is realized.

3.2.2 *Checking of Measuring Equipment* — An acoustic check of the sound level measuring equipment and at least one band of the analyzing equipment shall be made immediately before and after making the machine noise measurements. These site checks shall be supplemented by more detailed laboratory calibrations of the whole measuring equipment made at least once every two years.

3.2.3 *Location of Instruments and Observer* — The sound level meter case and any measuring amplifiers or filters shall be at least 0·3 m from the microphone, and the observer at least 1 m from the microphone, to prevent errors due to reflections from these objects. The calibration axis of the microphone should be pointed normal to the enveloping surface of the machine.

3.2.3.1 In the case of portable or hand-held sound level meters having integral microphone or other instrument, it shall be held steadily by the observer at arms length (stretched hands) and at a suitable angle convenient for taking accurate observations on the meter.

3.3 Test Measurements — The method described in this clause is applicable to the measurement of sound radiation in a free field over a reflecting plane. This is the standard environment for noise tests made in accordance with this standard.

Where conditions depart significantly from free-field conditions, the method described for semi-reverberant field conditions may be used by agreement between the manufacturer and the purchaser.

3.3.1 *Test of Room Suitability* — The room suitability shall be established by placing a small broad-band noise source (preferably non-aerodynamic) at the position to be occupied by the geometric centre of the machine to be tested, and determining the mean sound level at the measurement positions and at corresponding positions at half their distance from the source. The difference between these mean sound pressure levels at full and half distance should be at least 5 dB for each frequency band employed. Calculation of the mean values shall be made in accordance with **3.4.1**. For large machines such a test cannot always be performed. In such cases this fact should be stated in the test report.

NOTE — If the machine on test is sufficiently small with respect to the size of the room and of broad-band noise character, it may be taken as a reference source.

*Specification for sound level meters.

3.3.2 *Method of Measurement* — For all machines, measurements shall be made on the prescribed paths shown in Fig. 2, 3 or 4. For machines having a maximum linear dimension l (excluding shaft) equal to or exceeding 0·25 m these rectilinear paths are, at their nearest points, 1 m from the distance of the machine. For cases where l is less than 0·25 m, these rectilinear paths are at their nearest points at a distance from the surface of the machine between $4l$ and 1 m but not less than 0·25 m. For all horizontal machines the prescribed path parallel to the reflecting ground plane should be at shaft height or 0·25 m, whichever is greater (*see* Fig. 2). For vertical machines, the prescribed path parallel to the reflecting ground plane shall be at half the height of the machine but not less than a height of 0·25 m (*see* Fig. 4). The prescribed path in the vertical plane may be in, or parallel to, the plane of the shaft.

3.3.3 *Location of Measurement Points* — The positions of the measurement points (the number of which depends upon the size of the machine and the symmetry of the acoustic radiation, but should be at least five) should be as indicated in Fig. 2, 3 or 4.

The measurement points on each path should be at intervals of not more than 1 m from the five key measurement points.

If measurements at these points indicate levels which exceed the mean level (calculated in accordance with **3.4.1**) by more than 5 dB, additional points should be added midway between all the measurement points already in use. In some cases the acoustic radiation pattern of the mechine requires the use of extra paths. The extra paths shall maintain the basic symmetry of the measurement points.

3.3.4 *Quantities to be Determined* — At each measurement point the sound level in dB(A) is measured. The measurements at each point should be corrected for the effects of any background noise (*see* **3.1.2**). Any corrections indicated by the calibration checks shall also be taken into account.

3.3.4.1 No other correction shall be applied for the effects of test environment.

3.4 Evaluation of Test Measurement

3.4.1 *Calculation of the Mean Sound Level (A)* — The mean sound level (A) shall be calculated from the results of the measurements at all the test positions, after correction in accordance with **3.1.2**, by averaging as follows:

$$L_{AM} = 10 \log_{10} \left[\frac{1}{n} \left(\text{antilog}_{10} \frac{L_{A1}}{10} + \text{antilog}_{10} \frac{L_{A2}}{10} + \ldots + \text{antilog}_{10} \frac{L_{An}}{10} \right) \right] \quad \ldots\ldots (1)$$

where

L_{AM} = mean sound level (A) (dB);

L_{A1} = sound level (A) at the first measurement positions (dB);

L_{An} = sound level (A) at the nth measurement positions (dB); and

n = number of measurement positions.

NOTE 1 — When the dB readings at the various measurement points do not differ by more than 5 dB, an arithmetic average of the dB readings may be used. This will give a result differing by not more than 0·7 dB from that given in equation (1).

NOTE 2 — The application of equation (1) is facilitated by the use of Appendix E (*see* Example 1, Appendix A).

3.4.2 *Calculation of the Radius of the Equivalent Hemisphere* — For the purpose of calculation of the (A) weighted sound power level of the machine, the measurement made along the prescribed paths of Fig. 2, 3 and 4 shall be assumed to have been made over a hemisphere of radius r_s; where

$$r_s = \left[\frac{a\ (b + c)}{2} \right]^{\frac{1}{2}} \qquad \text{......(2)}$$

where a, b and c are as indicated in Fig. 2, 3 and 4.

NOTE — This expression for r_s is impirical and does not purport to be derived from any particular measurement surface.

3.4.3 *Calculation of (A) weighted Sound Power Level* — The (A) weighted sound power level of the machine can be calculated using the expression below or the curve in Fig. 5:

$$L_{WA} = L_{Am} + 10 \log_{10} \frac{2\ \pi\ r_s^2}{S_0} \qquad \text{......(3)}$$

where

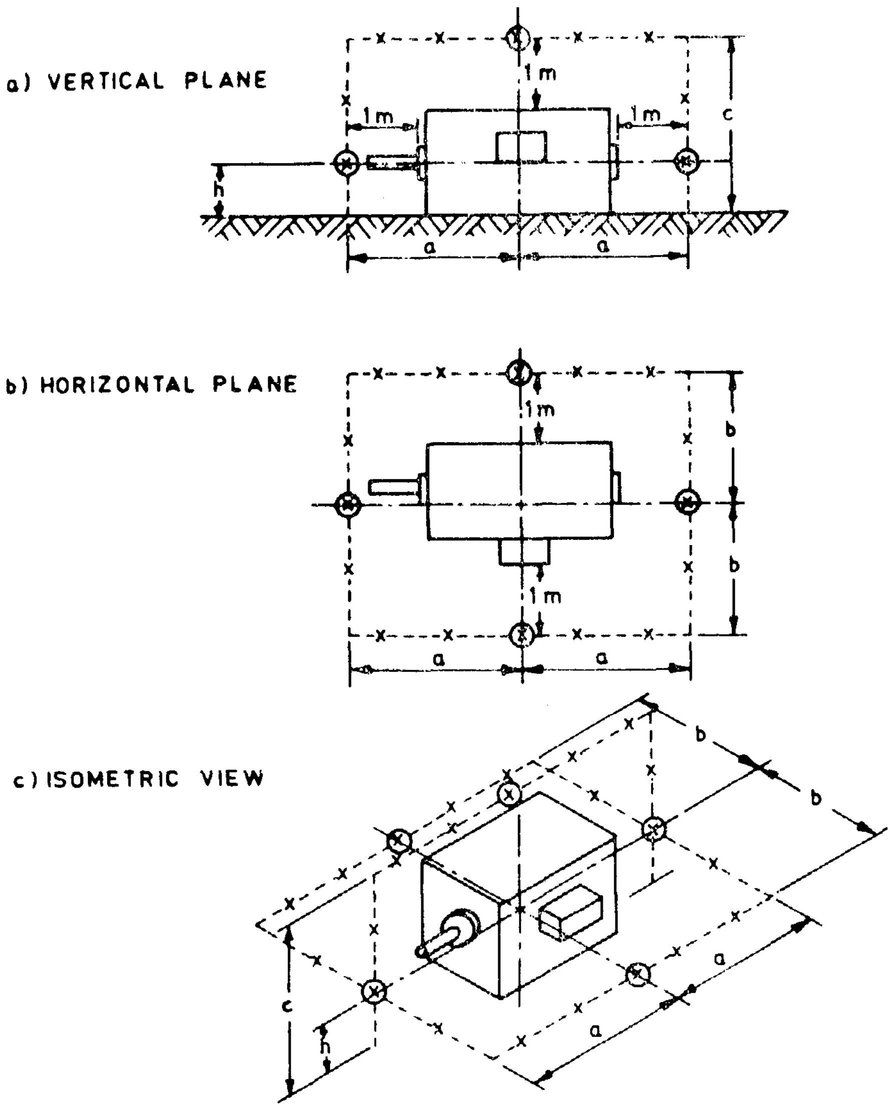
L_{WA} = (A) weighted sound power level, and

S_0 = reference area of 1 m².

4. TEST METHOD II

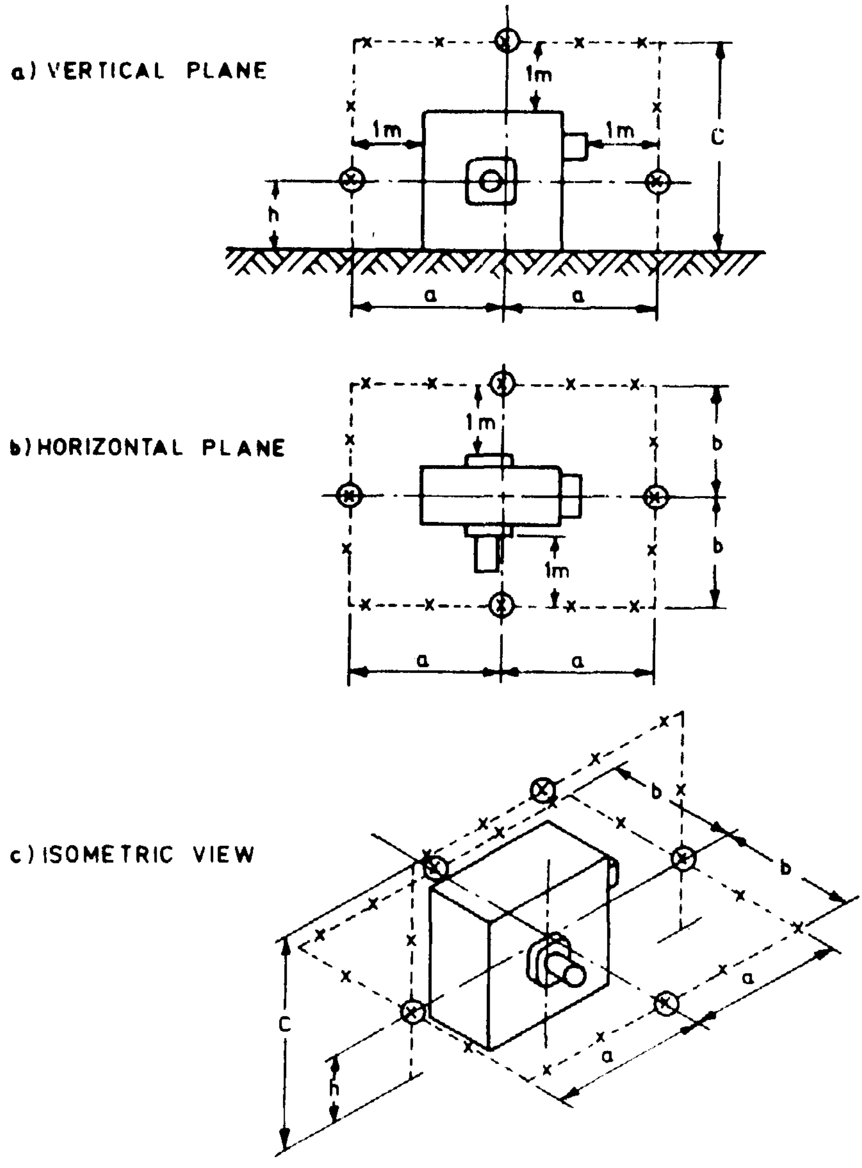
4.0 These tests include detailed measurements based on frequency band analysis of sound radiation in a free field over a reflecting plane.

4.0.1 Where free-field conditions cannot, in practice, be achieved, the method may still be used but the sound power level will be slightly higher than that obtained under free-field conditions. Alternatively, the method described in Appendix C for semi-reverberant conditions may be used.



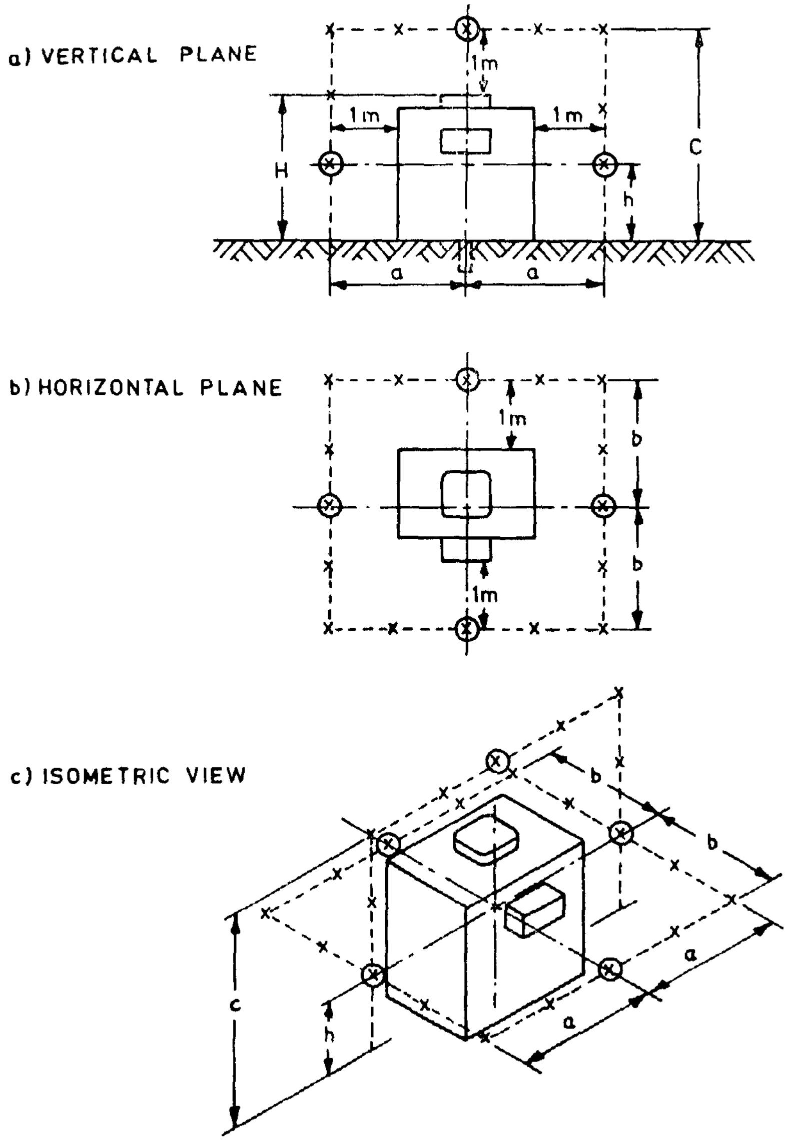
⊗ = Key measuring points.
x = Measuring points.

FIG. 2 LOCATION OF MEASURING POINTS AND PRESCRIBED PATHS FOR HORIZONTAL MACHINES WITH AXIAL LENGTH GREATER THAN OR EQUAL TO THE WIDTH



⊗ = Key measuring points.
× = Measuring points.

Fig. 3 Location of Measuring Points and Prescribed Paths for Horizontal Machines with Axial Length Shorter Than the Width



NOTE — $h = \frac{H}{2}$ but not less than 0·25 m.

⊗ = Key measuring points.
× = Measuring points.

FIG. 4 LOCATION OF MEASURING POINTS AND PRESCRIBED PATHS FOR VERTICAL MACHINES

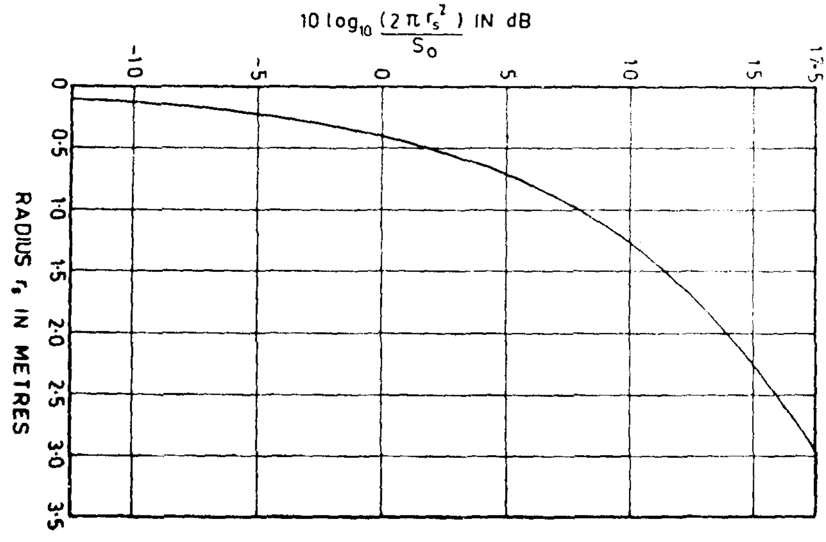


FIG. 5 VARIATION OF $10 \log_{10} \dfrac{(2 \pi r_s^2)}{S_0}$ WITH r_s

4.0.2 In all cases where the (A) weighted sound power level of a machine measured in accordance with Test Method I (*see* **3**) is greater than 93 dB (A) or one or more tones are prominent, noise measurements shall be made in accordance with this section.

4.1 Test Conditions

4.1.1 *Test Environment* — *See* **3.1.1**.

4.1.2 *Background Noise* — As in **3.1.2** for each octave band.

4.1.3 *Operating Conditions of Machines on Test* — *See* **3.1.3**.

4.1.4 *Mounting of Machine* — *See* **3.1.4**.

4.2 Measuring Instruments

4.2.1 *Grade* — The sound level meter shall comply with IS : 9779-1981*. The instructions in the use of the equipment shall be complied with to ensure that the intended degree of precision is realized. The meter shall be used on linear response or on (C) weighting for frequency analysis.

*Specification for sound level meters.

4.2.1.1 Octave and one-third octave band pass filters used for noise analysis shall comply with IS : 6964-1973*.

4.2.2 *Checking of Measuring Equipment* — *See* **3.2.2**.

4.3 Test Measurements — The method described in this clause is applicable to the measurement of sound radiation in a free field over a reflecting plane. This is the standard environment for noise tests made in accordance with this standard.

4.3.0 Where conditions depart significantly from free field conditions, the method described for semi-reverberant field conditions may be used by agreement between the manufacture and the purchaser.

4.3.1 *Test of Room Suitability* — *See* **3.3.1**.

4.3.2 *Method of Measurement* — *See* **3.3.2**.

4.3.3 *Location of Measurement Points* — *See* **3.3.3**.

4.3.4 *Quantities to be Determined* — The following quantities shall be determined at each of the measurement points in accordance with **4.3.2**:

a) Sound level in dB (A); and

b) Band sound pressure levels in the octave bands centred on 63 to 8 000 H_z with the sound level meter set to linear response or (C) weighting. Where linear response is not available, (C) weighting is sufficiently close to linear response over the above frequency range.

At each measurement point the sound level in dB (A) is measured. The measurement at each point should be corrected for the effects on any background noise (*see* **3.1.2**). Any correction indicated by the calibration checks shall also be taken into account. Unless it has been agreed to use the semireverberant method (*see* Appendix C), no other correction shall be applied for the effects of test environment.

4.4 Evaluation of Test Measurement

4.4.1 *Calculation of Octave Band Mean Sound Pressure Level* — The mean sound pressure levels for each octave band shall be calculated from the results of the measurements at all the test positions (after correcting for background noise in accordance with **3.1.2**) by averaging in accordance with equation (4).

$$L_{pM} = 10 \log_{10}\left[\frac{1}{n}\left(\text{antilog}_{10}\frac{L_{p1}}{10} + \text{antilog}_{10}\frac{L_{p2}}{10} + \ldots + \text{antilog}_{10}\frac{L_{pn}}{10}\right)\right] \quad \ldots\ldots(4)$$

*Octave, half-octave and third-octave band filters for analysis of sound and vibrations.

where

L_{pm} = octave band mean sound pressure level (dB);

L_{p1} = octave band sound pressure level at the first measurement point (dB);

L_{pn} = octave band sound pressure level at nth measurement point (dB); and

n = number of measurement points.

NOTE 1 — If $\frac{1}{3}$ octave readings are taken, the band energy levels to be summed in groups of three on an energy basis to obtain the octave band levels in accordance with equation(5).

$$L_{pi} = 10 \log_{10}\left[\text{antilog}_{10} \frac{L_{3(j-1)}}{10} + \text{antilog}_{10} \frac{L_{3(j)}}{10} + \text{antilog}_{10} \frac{L_{3(j+1)}}{10}\right] \qquad \ldots\ldots(5)$$

where

L_{pi} = calculated full octave band sound pressure level (dB);

$L_{3(j-1)}$ = sound pressure level in the ($j-1$)th $\frac{1}{3}$ octave band (dB);

$L_{3(j)}$ = sound pressure level in the jth $\frac{1}{3}$ octave band (dB); and

$L_{3(j+1)}$ = sound pressure level in the $(j+1)$th $\frac{1}{3}$ octave band (dB).

NOTE 2 — When the dB reading at the various measurement points do not differ by more than 5 dB, an artithmetic average of the dB readings may be used. This will give a result differing by not more than 0·7 dB from that given in equation (4).

NOTE 3 — The application of equation (4) is facilitated by the use of Appendix E (*see* example 1, Appendix A).

4.4.2 *Calculation of the Mean Sound Level (A) — See* **3.4.1.**

4.4.3 *Calculation of the Radius of the Equivalent Hemisphere — See* **3.4.2.**

4.4.4 *Evaluation of the Octave Band Mean Sound Power Levels* — The octave band mean sound power level may be calculated directly from the octave band mean sound pressure levels using equation (6).

$$L_w = L_{pm} + 10 \log_{10} \frac{2\pi r_s^2}{S_0} \qquad \ldots\ldots(6)$$

where

L_w = octave band mean sound power level re. 10^{-12} watts (dB);

L_{pm} = octave band mean sound pressure level (dB); and

S_0 = a reference area of 1 m^2.

4.4.4.1 Equation (6) holds for an ambient temperature of 20°C and barometric pressure of $9{\cdot}8 \times 10^4$ N/m^2 (Pa).

NOTE — Over the temperature range 0 to 40°C and over the range of barometric pressure from $9{\cdot}0 \times 10^4$ to $10{\cdot}6 \times 10^4$ N/m^2 (Pa), possible correction for ambient conditions is not greater than $\pm 0{\cdot}5$ dB. For this reason, such a correction has been omitted.

4.4.5 *Evaluation of the Octave Band Mean (A) Weighted Sound Pressure Levels* — The octave band mean sound pressure levels dc can be converted into equivalent octave band (A) weighted sound pressure levels by applying the following weighting corrections:

Octave Band Centered On Hz	dB *Correction*
31·5	− 39
63	− 26
125	− 16
250	− 9
500	− 3
1 000	0
2 000	+ 1
4 000	+ 1
8 000	− 1

4.4.6 *Evaluation of the Octave Band Mean (A) Weighted Sound Power Levels*— The octave and mean (A) weighted sound power levels may be calculated from the derived octave band mean (A) weighted sound levels using equation (3) in **3.4.3** and changing the symbols from total to octave band values.

4.4.7 *Evaluation of Acceptability Rating* — From the results of the (A) weighted octave band sound power level evaluation, the difference between the sound power level in each octave band judged to contain a pure tone or pure tones and the average level in the adjacent bands is calculated.

4.4.7.1 The acceptability rating is obtained by applying the correction K to the dB (A) sound power level measured in accordance with Test Method I.

4.4.7.2 When a pure tone is in an octave band above 250 Hz:

$$K = D$$

When the pure tone is in the octave band equal to or below 250 Hz:

$$K = \frac{D}{2}$$

When D is the greatest positive difference between the (A) weighted sound power level in any octave band containing a pure tone or pure tones, and the mean (A) weighted sound power level of the adjacent octave bands.

NOTE — The mean (A) weighted sound power level of the adjacent bands should be deduced using the table of Appendix E.

4.4.7.3 The corrected value of (A) weighted sound power level is the value used in comparison with the specified limit, and it shall not exceed the appropriate value given in Appendix D.

5. PRESENTATION OF RESULTS

5.1 Result of Tests in Accordance with Method I — The following information and test results shall be noted for all tests in accordance with **3**:

a) Reference to this Indian Standard — Ref ISS 12065;

b) Test on room suitability;

c) Description of the machine, its conditions of installation and operation;

d) Dimensioned sketch of the test room showing the location of the machine and any significant objects in the immediate vicinity;

e) Meteorological conditions of test, namely, ambient temperature (°C), relative humidity (percent) and barometric pressure [Nm² (Pa)];

f) Make, model and serial number of sound level meter used;

g) Position of measurement points relative to machine;

h) Results of sound level measurements (A) at each measurement point;

j) Background sound level (A) at each measurement point;

k) Results of corrected sound level measurements (A) at each measurement point;

m) Radius r_s and area S of the equivalent hemispheres; and

n) Mean sound power level (A).

5.2 Results of Tests in Accordance with Method II — The following information and test results shall be noted for all tests in accordance with **4**:

a) Reference to this Indian Standard — Ref ISS 12065;

b) Test on room suitability (*see* **3.3.1**);

c) Description of the machine, its conditions of installation and operation;

d) Dimensioned sketch of the test room showing the location of the machine and any significant objects in the immediate vicinity;

e) Meteorological conditions of test, namely, ambient temperature (°C), relative humidity (percent) and barometric pressure [N/m^2(Pa)];

f) Make, model and serial numbers of microphone, sound level meter and frequency analyzer used stating filter band width and centre frequencies;

g) Position of measurement paints relative to machine;

h) Band sound pressure level measurements at each measurement point;

j) Background band sound pressure level measurements at each measurement point;

k) Band sound pressure level measurements at each measurement point, after correction for background noise;

m) Sound level measurements (A) at each measurement point;

n) Background sound level (A) measurements at each measurement point;

p) Corrected sound level measurements (A) at each measurement point;

q) The radius r_s and area S of the equivalent hemisphere;

r) Mean sound power level (A) as determined in accordance with Test Method I (*see* **3**);

s) The octave band mean sound pressure levels calculated in accordance with **4.4.1**;

t) The calculated mean octave band sound power levels; and

u) The acceptability rating determined in accordance with **4.4.7.**

5.3 Test Certificates

5.3.1 *Test Certificates for Test Method I* — These shall include the mean (A) weighted sound power determined in accordance with **3.4.3.**

5.3.2 *Test Certificates for Test Method II* — These shall include the mean (A) weighted sound power level determined in accordance with **3.4.3,** the mean (A) weighted octave band sound power levels determined in accordance with **4.4.6**, and the acceptability rating, where appropriate.

6. CLASSIFICATION OF MACHINES IN TERMS OF dB (A) SOUND POWER EMITTED

6.0 Machines may be divided into three classes according to the dB (A) sound power.

6.1 Normal Sound Power — Machines in this class are of the manufacturers' standard design where the output has not been limited or special acoustic treatment provided to reduce the noise emitted. Limiting dB (A) sound power values for standard machines rated up to 16 000 kW are given in Appendix D.

6.2 Reduced Sound Power — Sound power values for machines in this class will not exceed the values given in Appendix D reduced by 5. Machines in this class are basically of the manufacturer's standard design but may have some simple modification or modifications, for example, special fans to obtain a moderate reduction in the noise emitted. Such modification may not be practicable for standard machines below 132 kW.

6.3 Specially Low Sound Power — Machines in this class may have special electrical and mechanical design to obtain sound power level below the classes in **6.1** or **6.2** for specific applications. The sound power values for machines in this class are a matter for agreement between the manufacturer and the purchaser.

APPENDIX A

[*Clauses* 3.1.2 2, 3.4.1 (*Note* 2) *and* 4.4.1 (*Note* 3)]

EXAMPLES

A-1. EXAMPLE 1

A-1.1 Type tests on a machine gave the following corrected sound pressure level readings in dB at the test positions for the 2 000 Hz centre frequency octave band:

$L_{p1} = 87$; $L_{p2} = 92$; $L_{p3} = 86$; $L_{p4} = 92$; $L_{p5} = 85$; $L_{p6} = 83$; $L_{p7} = 93$; $L_{p8} = 90$; $L_{p9} = 84$

$$a = 1{\cdot}8 \text{ m}$$

$$b = 1{\cdot}1 \text{ m}$$

$$c = 2{\cdot}7 \text{ m}$$

It is required to find the mean sound pressure level at radius r_s and the octave band sound power level.

A-1.2 Method — Since the readings differ by more than 5 dB the arithmatic average may not be taken. It is, therefore, necessary to use the method of **3.4**. For each value of L_p in col. 1 read off the corresponding figure in col. 2 of the table in Appendix E.

For

L_{p1} corresponding value in col 2 equals 501 $\times 10^6$

L_{p2} corresponding value in col 2 equals 1 590 $\times 10^6$

L_{p3} corresponding value in col 2 equals 398 $\times 10^6$

L_{p4} corresponding value in col 2 equals 1 590 $\times 10^6$

L_{p5} corresponding value in col 2 equals 316 $\times 10^6$

L_{p6} corresponding value in col 2 equals 200 $\times 10^6$

L_{p7} corresponding value in col 2 equals 2 000 $\times 10^6$

L_{p8} corresponding value in col 2 equals 1 000 $\times 10^6$

L_{p9} corresponding value in col 2 equals 251 $\times 10^6$

Total 7 846 $\times 10^6$

A-1.3 Divide the sum by the number of reading (9) obtaining $871 \cdot 8 \times 10^6$. Read off in col 1 the nearest value opposite $871 \cdot 8 \times 10^6$ in col 2, that is, 89·5 dB.

$L_{pM} =$ 89·5 dB is the mean sound pressure level for the octave band centred on 2 000 Hz,

The radius of the equivalent hemisphere, r_s, from **3.4.2** is given by:

$$r_s = \left[\frac{1 \cdot 8 \; (1 \cdot 1 + 2 \cdot 7)}{2} \right]^{\frac{1}{2}} = 1 \cdot 85 \text{ m}$$

From Fig. 5 read the ordinates r = 1.85 m, that is, 13·5 dB (to the nearest whole number or whole number + 0·5 dB).

L_W for the 2 000 Hz centre frequency octave band is obtained by adding the value just obtained to the mean octave band sound pressure level.

$$L_W = L_{pm} + 10 \log_{10} \frac{2\pi \, r_s^2}{S_0}$$

$$= 89 \cdot 5 + 13 \cdot 5 = 103 \cdot 0 \text{ dB.}$$

A-2. EXAMPLE 2

A-2.1 Tabulated below are the octave band L_W values for a machine with an IP44 enclosure and rated at 132 kW, 2 970 rev/min. It is required to find the (A) weighted shound power level and the acceptability rating for the machine. A pure tone is judged prominent in the octave band centred on 1 000 Hz.

Octave band centre frequencies

Hz	63	125	250	500	1 000	2 000	4 000	8 000
L_W	93·5	97·5	98·5	99·0	104·0	99·0	95·5	83·5
Correction	—26	—16	—9	—3	0	+1	+1	—1
L_{WA}	67·5	81·5	89·5	96·0	104·0	100·0	96·5	82·5

The 1 000 Hz band contains a pure tone and its level is appreciably greater than the adjacent bands. The mean (A) weighted sound power level of the adjacent 500 Hz and 2 000 Hz bands is 98·5 dB (using Appendix E), so the difference between this level and the 1 000 Hz band level is 5·5 dB.

The correction K is D where D is 5·5 dB, so K = 5·5.

The overall (A) weighted sound power level of the machine is 106·5 dB.

However, taking the effect of pure tone into account, the acceptability rating is 106·5 + 5·5 = 112·0.

The machine, therefore, does not comply with limits specified in this standard.

A-3. EXAMPLE 3 — BACKGROUND CORRECTION

A-3.1 The total sound level at a point is 75 dB and the background sound level is 70 dB. It is required to determine the sound level of the source at the measurement point.

From Appendix E,

	Column 1	*Column 2*
Total sound level 75 dB		$31{\cdot}6 \times 10^6$
Background sound level 70 dB		$10{\cdot}0 \times 10^6$
Difference		$21{\cdot}6 \times 10^6$

Reading in col. 1, the nearest whole number or whole number +0·5 corresponding to $21{\cdot}6 \times 10^6$ in col 2 gives a source noise level of 73·5 dB.

Alternatively, using Fig. 1, the dB increase in noise level caused by the machine is 5 dB. The number of dB to be subtracted from the total sound level reading as the measuring point to the nearest whole number, or whole number +0·5, is 1·5 dB.

The source noise level is 75 − 1·5 = 73·5 dB.

APPENDIX B

(*Clause* 1.4)

RECOMMENDATIONS FOR METHODS OF ASSESSING NOISE OF MACHINES ON LOAD

B-1. The standard conditions for noise tests are that the machine should be on no-load and the sound be radiated in a free-field over a reflecting plane.

B-2. If it is apparent that there is a significant difference in the noise level of the machine between no load and rated load (or any other load) the magnitude of the difference may, by agreement between the manufacturer and the purchaser, be determined approximately from near field sound pressure level measurements.

B-3. This method consists of carrying out sound pressure level measurements at a number of points suitably distributed around the machine, sufficiently close to it so that the measurements are not significantly affected by nearby reflecting surfaces or background noise. The use of directional microphones for this test may be desirable.

B-4. The provisions of Test Methods I or II as appropriate apply in general with the exception of the section dealing with location of measurement points.

B-5. For near field measurements, the measurement points are located on an agreed prescribed surface.

B-6. Reading should be taken with the machine on no load and on the load for which the increase in noise level si required. The difference between these two readings is then added to the no load sound power value obtained by Test Method I or II as appropriate to give an approximation to the sound power value on load.

APPENDIX C

(*Clauses* 1.5, 4.0.1 *and* 4.3.4)

TEST METHOD FOR SEMI-REVERBERANT CONDITIONS

C-0. This appendix describes the measurements to be made when the test room does not qualify as giving free field over a reflecting plane and is not a reverberant or diffuse field.

When the noise radiated from a machine has marked directivity, measurement of the machine noise under semi-reverberant conditions should be regarded as an approximate method for machine noise measurement.

C-1. TEST CONDITIONS

C-1.1 Test Environment — Where the difference between the mean sound pressure levels at full and half distance is less than 5 dB but greater than 2 dB, semi-reverberant conditions may be assumed to exist.

C-1.2 Background Noise — As in **3.1.2** for each octave band.

C-1.3 Operating Conditions of Machine on Test — *see* 3.1.3.

C-1.4 Mounting of Machine — *See* **3.1.4.**

C-2. MEASURING INSTRUMENTS

C-2.1 Grade — *See* **4.2.1**.

C-2.2 Checking of Measuring Equipment — *See* **3.2.3**.

C-3. TEST MEASUREMENTS

C-3.0 The method described in this clause is applicable to the measurement of sound radiation in a semi-reverberant environment over a reflecting plane.

C-3.1 Test of Room Suitability — *See* **3.3.1**.

C-3.2 Method of Measurement — *See* **3.3.2**.

C-3.3 Location of Measurement Points — *See* **3.3.3**.

C-3.4 Quantities to be Determined — The following quantities should be determined at each of the measurement points determined from **C-3.2**:

a) Sound level in dB (A); and

b) Band sound pressure levels in the octave bands centred on 63 Hz to 8 000 Hz with the sound level meter set to linear response or (C) weighting. Where linear response is not available, (C) weighting is sufficiently close to linear response over the above frequency range.

The measurement at each point should be corrected for the effects of any background noise (*see* **3.1.2**). Any corrections indicated by the calibration checks, shall also be taken into account.

No other corrections shall be applied for the effects of test environment.

C-4. EVALUATION OF TEST MEASUREMENT

C-4.1 Calculation of Octave Band Mean Sound Pressure Levels — *See* **4.4.1**.

C-4.2 Calculation of Mean Sound Level (A) — *See* **3.4.1**.

C-4.3 Calculation of the Radius of the Equivalent Hemisphere — *See* **3.4.2**.

C-4.4 Evaluation of the Mean Sound Power levels in Octave Bands — The octave band sound power levels can be deduced from the octave band mean sound pressure levels by taking into account the influence of the test room on the measured sound pressure levels.

This effect can be determined by using a small non-directional broad-band reference sound source (some types of aerodynamic noise source may not be suitable) of known sound power.

The determination of the octave band sound power level of the reference source (L_{Wr}) should be determined in a free field above a reflecting plane as detailed in **4.4.4**.

The reference sound source should then be substituted for the machine on test in the semi-reverberant room and the octave band mean sound pressure levels obtained from measurements at the same measurement points as for the machine on test.

The octave band sound power level may be determined from the following equation:

$$L_W = L_{Wr} + L_{pM} - L_{pMr}$$

where

L_W = octave band sound power level re. 10^{-12} watts of the machine on test (dB);

L_{Wr} = octave band sound power level re. 10^{-12} watts of the reference source (dB);

L_{pM} = octave band mean sound pressure level re. 2×10^{-5} N/m² (Pa) of the machine on test (dB); and

L_{pMr} = octave band mean sound pressure level re. 2×10^{-5} N/m² (Pa) of the reference source (dB)

C-4.5 Evaluation of the Mean (A) Weighted Octave Band Sound Levels — *See* **4.4.5**.

C-4.6 Evaluation of the Mean (A) Weighted Octave Band Sound Power Levels — *See* **4.4.6**.

C-4.7 Evaluation of the Acceptability Rating — *See* **4.4.7**.

APPENDIX D

(*Clauses* 1.3, 3.0.1, 4.4.7.3, 6.1 *and* 6.2)

LIMITING MEAN SOUND POWER LEVEL L_W IN dB (A) FOR AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINES

Protective Enclosure		IP 22	IP 44	IP 22	IP 44	IP 22	IP 44	IP 22	IP 44	IP 22	IP 44	IP 22	IP 44
Rating kV (or kVA)		Rated Speed (rev/min)											
		960 and below		961 to 1 320		1 321 to 1 900		1 901 to 2 360		2 361 to 3 150		3 151 to 3 750	
Above	Up to	Sound Power Level dB(A)											
	1·1	—	76	—	79	—	80	—	83	—	84	—	88
1.1	2·2	—	79	—	80	—	83	—	87	—	89	—	91
2.2	5·5	—	82	—	84	—	87	—	92	—	93	—	95
5.5	11	82	85	85	88	88	91	91	96	94	97	97	100
11	22	86	89	89	93	92	96	94	98	97	101	100	103
22	37	89	91	92	95	94	97	96	100	99	103	102	105
37	55	90	92	94	97	97	99	99	103	101	105	104	107
55	110	94	96	97	101	100	104	102	105	104	107	106	109
110	220	98	100	100	104	103	106	105	108	107	110	108	112
220	630	100	102	104	106	106	109	107	111	108	112	110	114
630	1 100	102	104	106	107	107	111	108	111	108	112	110	114
1 100	2 500	105	107	109	110	109	113	109	113	109	113	110	114
2 500	6 300	106	108	110	112	111	115	111	115	111	115	111	115
6 300	16 000	108	110	111	113	113	116	113	116	113	116	113	116

NOTE 1 — IP 22 corresponds generally to drip-proof, ventilated and similar enclosures.
IP 44 corresponds generally to totally enclosed fan-cooled, closed air circuit air-cooled, and similar enclosures (*see* IS : 4691-1985*).

NOTE 2 — No positive tolerance is allowed on the above sound power levels.

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APPENDIX E

[*Clauses* 3 1.2.2, 3 4.1 (*Note* 2), 4.4.1 (*Note* 3), 4.4.7.2 (*Note*), A-1.2, A-2.1 *and* A-3.1]

CONVERSION TABLE

(1)	(2)	(1)	(2)	(1)	(2)
dB	$\times 10^6$	dB	$\times 10^6$	dB	$\times 10^6$
109·5	89 100	89·5	891	69·5	8·91
109	79 400	89	794	69	7·94
108·5	70 800	88·5	708	68·5	7·08
108	63 100	88	631	68	6·31
107·5	56 200	87·5	562	67·5	5·62
107	50 100	87	501	67	5·01
106·5	44 700	86·5	447	66·5	4·17
106	39 800	86	398	66	3·98
105·5	35 500	85·5	355	65·5	3·55
105	31 600	85	316	65	3·16
104·5	28 200	84·5	282	64·5	2·82
104	25 100	84	251	64	2·51
103·5	22 400	83·5	224	63·5	2·24
103	20 000	83	200	63	2·00
102·5	17 800	82·5	178	62·5	1·78
102	15 900	82	159	62	1·59
101·5	14 100	81·5	141	61·5	1·41
101	12 600	81	126	61	1·26
100·5	11 200	80·5	112	60·5	1·12
100	10 000	80	100	60	1·00
99·5	8 910	79·5	89·1	59·5	0·891
99	7 940	79	79·4	59	0·794
98·5	7 080	78·5	70·8	58·5	0·708
98	6 310	78	63·1	58	0·631
97·5	5 620	77·5	56·2	57·5	0·562
97	5 010	77	50·1	57	0·501
96·5	4 460	76·5	44·7	56·5	0·447
96	3 980	76	39·8	56	0·398
95·5	3 550	75·5	35·5	55·5	0·355
95	3 160	75	31·6	55	0·316
94·5	2 820	74·5	28·2	54·5	0·282
94	2 510	74	25·1	54	0·251
93·5	2 240	73·5	22·4	53·5	0·224
93	2 000	73	20·0	53	0·200
92·5	1 780	72·5	17·8	52·5	0·178
92	1 590	72	15·9	52	0·159
91·5	1 410	71·5	14·1	51·5	0·141
91	1 260	71	12·6	51	0·126
90·5	1 120	70·5	11·2	50·5	0·112
90	1 000	70	10.0	50	0·100

(*Continued from page* 2)

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IS 12065 : 1987 PERMISSIBLE LIMITS OF NOISE LEVELS FOR ROTATING ELECTRICAL MACHINES

(*Page* 27, *heading, col* 1) — Substitute 'kW(or kVA)' *for* 'kV(or kVA)'.

(ETD 15)

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